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Transverse Active Dampers for the Tevatron

As beam intensity approaches 3×10^{12} in the Tevatron resistive wall instabilities similar to those encountered in the FNAL Main Accelerator can be expected to develop. The threshold of such instabilities is estimated by considering the proximity of the beam to the side wall of the vacuum chamber and the factor of two lower wall resistance in the lower temperature Tevatron. Because of symmetry, both vertical and horizontal instabilities will occur at about the same intensity. The driving forces will be similar to those encountered in the Main Accelerator. A vertical and horizontal "slow" damper system similar to the ones used in the Main Accelerator^{1,2} could sufficiently damp the resistive wall instabilities. The basic parameters of a system capable of damping the growth of modes up to 350 KHz are tabulated in Table I, column 1.

A more stringent requirement may be the need to damp coherent oscillations due to 1) injection errors and 2) machine irregularities during acceleration. No attempt was made to estimate the magnitude of the second item. However, estimates based upon a proposed injection kicker design, predict ± 1 mm injection errors with 2 MHz structure relative to the beta max. position. With sufficient sextupole correction to control chromaticity the tune spread will be limited to 0.002. Something like 1000 oscillations will smear the coherent motion. To minimize the subsequent phase space spread (50% increase) the injection oscillations must be damped within 50 revolutions (1 msec)³. Table I, column 2 lists a system capable of damping the injection oscillations in about 1.0 msec. Significantly more power is required to damp the fixed error than to control an instability. This is because the required damping force varies as the inverse of particle

momentum and additional bandwidth is required to accomodate the injection error structure of 2 MHz.

At intensities ranging from 8×10^{12} to 1.4×10^{13} ppp we have experienced a threshold for single bunch instabilities in the FNAL Main Accelerator. The intensity threshold is not well defined but rather has a level which depends somewhat upon the chromaticity of the machine. The head-to-tail effect is presumed to drive the instability. Similar effects can be expected in the Tevatron and a "Superdamper" will be necessary at machine intensities of about 1×10^{13} ppp. Such a system is tabulated in Table 1, column 3.

The requirements in Table 1 column 1 and column 3, closely match the parameters respectively of the "slow" vertical and horizontal damper system and the vertical superdamper system in the Main Ring. Minor adjustments in electrode spacing and length of electrodes accomodate the Tevatron aperture. The system gain and, more important, the maximum kick per turn in the machine are equal for the two systems. If, which seems likely, an individual bunch-by-bunch damper will be necessary for both vertical and horizontal planes it may well be wise to start with a vertical and horizontal superdamper system in the Tevatron.

Several advantages are apparent with the superdamper system. 1) long delay cables and restrictions on location of pick-up and deflection electrodes so that signal time of flight paths meet the beam with correct timing are eliminated. 2) Digital delay can be used to conveniently switch the timing to reverse the direction of acceleration. 3) Directional properties of the position signal pick-up and deflection electrodes make $p-\bar{p}$ damping schemes possible.

Figure 1 suggests a system which could be assembled to damp accelerated $p\text{-}\bar{p}$ beams. It uses available component designs as used in the Main Ring vertical superdamper. Although \bar{p} intensities will be low, the \bar{p} will see wake fields from the p 's. Further understanding of the instability effects of such a system is required but if necessary a solution for damping exists. For p acceleration only, one simply replaces the \bar{p} channel with appropriate terminating resistors at the pick-up and deflection electrodes. Additional system gain can be obtained by adding more distributed amplifiers and deflection electrodes. Some investigative work into the directionality of the signal pick-up and deflection system is needed.

The system requirements for damping fixed injection errors in column 2 of Table 1 seems like an over-kill. An active damper of such high power may not be desirable since it's effectively on only for a msec in each machine cycle. If the structure can truly be predicted and controlled from one machine cycle to the next a pulsed ferrite damper, properly phased might well be investigated to correct the injection errors.

References

1. R. Steining, E.J.N. Wilson, and M. Cornacchia; "Initial Test of the Main Ring Vertical Beam Damper" Accelerator Experiment EXP-56, January 15, 1974.
2. R. Steining, and E.J.N. Wilson; "Transverse Collective Instability in the NAL 500 GeV Accelerator", Nuclear Instruments and Methods, 121 (1974) P 283-285.
3. S. Ohnuma, UPC No. 9/Rev. A, January 11, 1979.
4. R. Steining et.al.; "The Fermilab Transverse Instability Active Damping System", IEEE Transactions on Nuclear Science, Vol. NS-22, No. 3, 1975.

TABLE I

Tevatron Transverse Damper Requirements

Parameter	(1) "Slow" Damper Damps Low Frequency Instabilities	(2) "Slow-Hi Power" Damps Low Frequency Instabilities plus Injection Error Correction	(3) "Super" Damper Damps Individual Bunch Instabilities
Deflection Electrode Spacing	6.4 cm	6.4 cm	6.4 cm
Length	1.4 meters	2.8 meters (2 Sections)	1.4 meters
Driver Capacitance Per electrode	120 pf	120 pf/section	50 Ω terminated traveling wave structure
Bandwidth	10 kHz - 1 MHz	10 kHz - 5 MHz	≤ 2 nsec risetime
Deflection Voltage	± 2 kV	± 4.2 kV	± 2 kV 1/2 Electric, 1/2 Magnetic
Power (x Electrode)	1 kW (x2)	23 kW (x4)	10 kW (x2)
Damping time (150 GeV)	5 msec	1.0 msec	5 msec
System Gain (150 GeV)	$.96 \times 10^{-4}$ mrad/mm	4×10^{-4} mrad/mm	0.96×10^{-4} mrad/mm

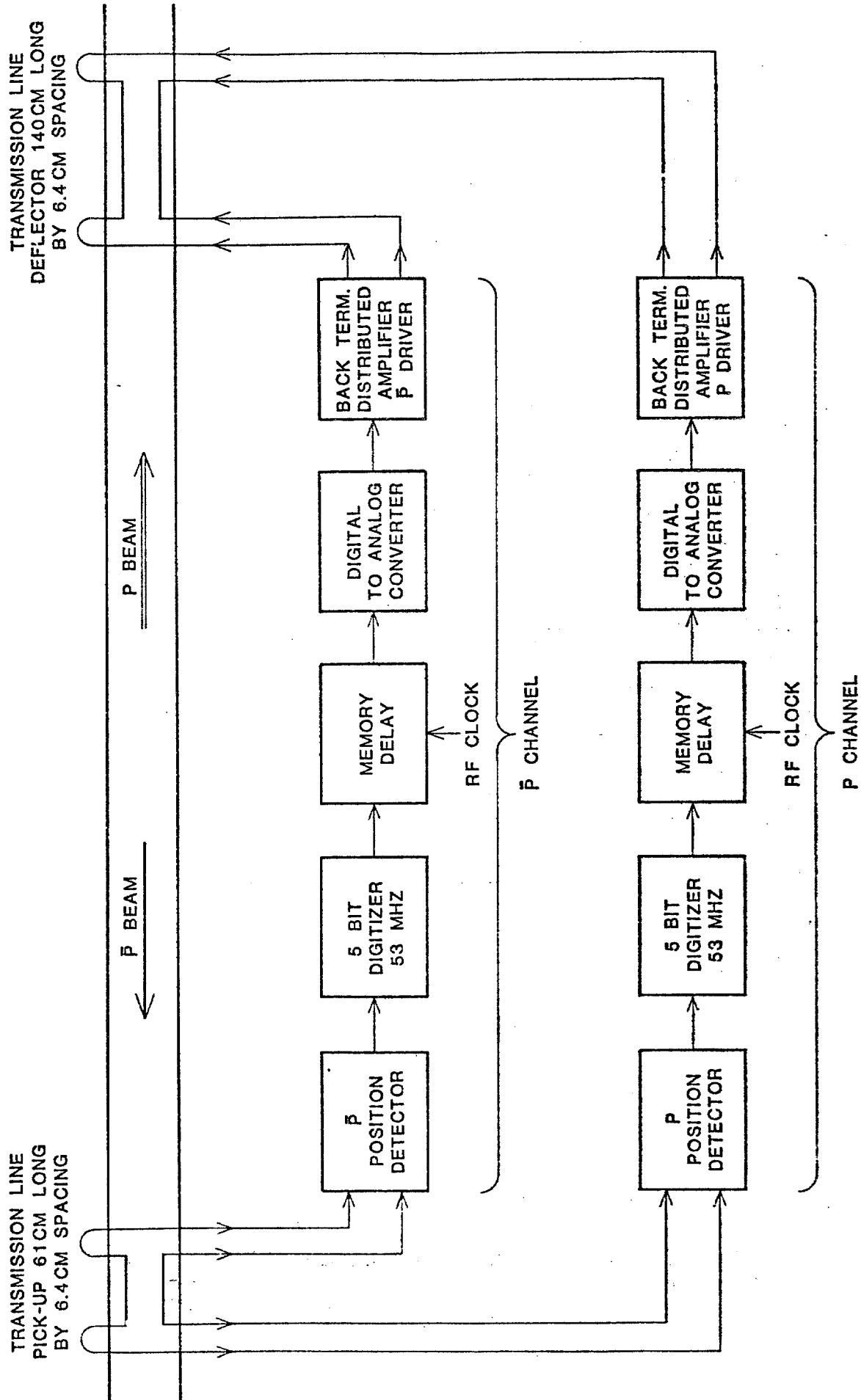


FIG-1 POSSIBLE TEVATRON TRANSVERSE P-P DAMPING SYSTEM